VERIFICATION OF TRANSLATION

I, Yoko Hanafusa, translator of 303, 2-15-11, Yamamotonaka, Takarazuka, Hyogo, Japan, hereby declare that I am conversant with the English and Japanese languages and am a competent translator thereof. I further declare that to the best of my knowledge and belief the following is a true and correct translation made by me of Japanese Patent Application No. 11-020701 filed on January 28, 1999.

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Yoko Hanafusa

YOKO HANAFUSA

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[INVENTOR]

[ADDRESS] c/o Matsushita Electric Industrial Co., Ltd.
1006, Kadoma, Kadoma-City, Osaka

[NAME] AOKI Masaki

[ADDRESS] c/o Matsushita Electric Industrial Co., Ltd.
1006, Kadoma, Kadoma-City, Osaka

[NAME] SHIOKAWA Akira

[ADDRESS] c/o Matsushita Electric Industrial Co., Ltd.
1006, Kadoma, Kadoma-City, Osaka

[NAME] TAKADA Yuusuke

[ADDRESS] c/o Matsushita Electric Industrial Co., Ltd.
1006, Kadoma, Kadoma-City, Osaka

[NAME] MURAI Ryuichi

[APPLICANT]

[CODE NO.] 000005821

[NAME] Matsushita Electric Industrial Co., Ltd.

[PATENT AGENT]

[CODE NO.] 100090446

[PATENT ATTORNEY]

[NAME] NAKAJIMA Shiro

[PATENT AGENT]

[CODE NO.] 100109210

[PATENT ATTORNEY]

[NAME] NII Hiromori

[CHARGES]

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Specification 1

Drawings 1

Abstract 1

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[PROOF] Necessary

[DOCUMENT] Specification

[TITLE OF THE INVENTION] Plasma display panel, and production method thereof

[CLAIMS]

[CLAIM 1] A plasma display panel, wherein

plural pairs of display electrodes in column direction are provided on the first plate so as to be sandwiched between the first plate and a dielectric layer which is for covering the first plate, the first plate and a second plate are opposed to each other with a plurality of address electrodes in row direction therebetween, each area between one address electrode and a pair of display electrodes forms a cell, and a discharge gas is filled into each of cells, and wherein

at least one of a thickness of the dielectric layer and a gap between a pair of display electrodes is adjusted to generate an electric field having 5V/cm・Torr or more equivalent electric field strength within the cells, and the discharge gas contains xenon with at least 5% pressure.

[CLAIM 2] The plasma display panel of CLAIM 1, wherein

the dielectric layer has a thickness of 10-25μm.

[CLAIM 3] The plasma display panel of CLAIM 1, wherein

each of the display electrodes is made up of a bus line and a transparent electrode, the dielectric layer is made up of a first dielectric layer covering the display electrodes, and a second dielectric layer accumulated over the first dielectric layer so as

to correspond to where the bus lines are, and the first dielectric layer has a thickness of 3-5 μm.

[CLAIM 4] The plasma display panel of any one of CLAIMS 1-3, wherein

one display electrode of each of the pairs is provided with one or more protrusions that are opposed to the other electrode of the pair.

[CLAIM 5] The plasma display panel of CLAIM 4, wherein

the protrusions are provided so that each cell has one protrusion.

[CLAIM 6] The plasma display panel of any one of CLAIMS 1-5, wherein

a gap between each pair of the display electrodes is 20-70 μm, and a pressure of xenon (Xe) within the discharge gas is 15-90%.

[CLAIM 7] A production method of a plasma display panel, the production method comprising:

a first step of providing a dielectric layer for a first plate with a plurality of display electrodes therebetween;

a second step of placing the first plate and the second plate to face each other, with a plurality of address electrodes therebetween, and of filling a discharge gas to cells, each of the cells being a corresponding area formed between one address electrode and a pair of display electrodes, wherein

at the first step, each of the display electrodes is constituted by a bus line and a transparent electrode, and the dielectric layer is constituted by: a first layer covering the display electrodes; and a second layer accumulated over the first layer so as to correspond to where the bus lines are, the first layer having a thickness of 3-5 μm.

[CLAIM 8] The production method of CLAIM 7, wherein

at the first step, the dielectric layer is produced using glass particles that have an average particle diameter of 0.1-1.5 μm.

[DETAILED DESCRIPTION OF THE INVENTION]

0001

[FIELD OF THE INVENTION]

The present invention relates to a plasma display panel used for such as display devices, and also relates to a production method of such a plasma display panel.

0002

[DESCRIPTION OF THE RELATED ART]

Recently, there have been increasing needs for high quality, large screen display devices such as high-definition televisions. Among them, CRTs have advantages in resolution and luminance. CRTs are, however, are not ideal for screens of 40 inches or more, since they are destined to enlarge their depth and weight when the screens become large. Liquid crystal displays (LCD), on the other hand, have advantages in that they consume little electricity and their driving voltage is low. However, LCDs have limitations in size of the screen, and in viewing angle.

0003

PDPs, on the contrary, make it possible to create large screens. Indeed, PDP products with 50-inch diagonal screen, have been developed.

FIG. 4 is a sectional perspective view showing only the main structure of an alternating current surface-discharge type PDP. In this drawing, the direction z signifies a thickness direction of the

PDP, and x-y plane signifies a parallel plane to the PDP surface. As shown in this drawing, the present PDP is composed of a front panel 20 and a back panel 26, whose respective main surfaces are opposed to each other.

0004

A front panel glass 21 functions as a substrate of the front panel 20. On one surface of the front panel glass 21, a pair of display electrodes 22 and 23 (X electrode 22, and Y electrode 23) are arranged along the direction x, and surface discharge is performed between the pair of display electrodes 22 and 23. Throughout the surface of the front panel glass 21 on which the display electrodes 22 and 23 have been provided, a dielectric layer 24 is coated. And a protection layer 25 is further coated on the dielectric layer 24.

0005

A back panel glass 27 functions as a substrate of the back panel 26. On one surface of the back panel glass 27, a plurality of address electrodes 28 are arranged in stripe-pattern, at a given interval and with their lengthwise direction corresponding to the direction y. A dielectric film 29 is coated throughout the back panel glass 27, so as to cover the address electrodes 28. On the dielectric film 29, ribs 30 are provided so as to correspond to the gaps created between each adjacent address electrodes 28. Phosphor layers 31-33, each layer corresponding to one of red (R), green (G), and blue (B), are provided for the spaces created between adjacent ribs, so that in each of the spaces, one phosphor layer is provided on the side walls of the two ribs 30, and on the surface of the dielectric film 29.

0006

The front panel 20 and the back panel 26, having the above structures, are attached and sealed at the rims, so as to face the address electrodes 28 and the display electrodes 22 and 23, in a manner that the lengthwise direction of the address electrodes 28 is orthogonal to the lengthwise direction of the display electrodes 22 and 23. Between the both panels 20 and 26, a discharge gas (sealing gas) that contains Xe is filled at a predetermined pressure (normally, about 300-500 Torr). The spaces created between adjacent ribs 30 form discharge spaces 38, and an area formed at an intersection of an address electrode 28 and the pair of display electrodes 22 and 23 becomes a cell that plays a role in image display (the cell not shown in the drawings). At the driving start of the PDP, discharge starts somewhere between the address electrodes 28 and the display electrodes 22 and 23, so as to generate ultraviolet light having short wavelength (i.e. Xe resonance line, having wavelength of about 147 nm), enabling image display due to light emission from the phosphor layers 31-33.

0007

[THE PROBLEMS THE INVENTION IS GOING TO SOLVE]

Incidentally, full-spec high-definition televisions of 42 inch class, which are receiving attention these days, have 1920*1125 pixels and cell pitch of 0.15mm*0.48mm. In such televisions, the cell size is 0.072 mm^2, which is 1/7 to 1/8 that of NTSC televisions. Therefore, if PDPs for high-definition televisions of a 42-inch diagonal screen are to be made with conventional cell structures, the panel's efficiency (luminous efficiency) and the luminance are expected to be reduced to about 0.15-0.17 lm/w and 50-60 cd/m^2,

respectively.

0008

For such PDPs to achieve the same brightness as CRTs conforming to the NTSC standard, which is about 500cd/m^2, it is required to increase the panel's efficiency by 10 times or more (consult with FLATPANEL DISPLAY 1997 Part 5-1, pp.200 for details). In view of such backgrounds, it is desired to improve the efficiency of the PDP.

0009

The light emitting principle of conventional PDPs is basically the same as that of fluorescent lamps; incident to glow discharge, an ultraviolet light (Xe resonance line; about 147 nm) is emitted from a discharge gas, so as to emit phosphors of red, green, and blue, by excitation. However, the xenon resonance line does not have high efficiency in converting the phosphors into visible light, and so it is difficult to efficiently obtain the same high luminance as the fluorescent lamps. In addition, the xenon resonance line has a characteristic of absorbing itself, and so converting rate into ultraviolet light is low (see "Latest plasma display production technology", Part 2, discussion for parts and materials, pp. 290). Specifically, it is known that, with PDPs with gas compositions of He-Xe, or Ne-Xe, the percentage of the supplied electric energy converted to ultraviolet light is about 2%, and furthermore only 0.2% of the electric energy is converted to visible light (refer to "Applied Physics" Vol.51, No. 3, 1982, pp. 344-345, "Optical Technology Contact" Vol. 34, No. 1, 1996, pp. 25, and "FLAT PANEL DISPLAY", 1996, Part5-3, "NHK technology Research Vol. 31, No. 1, 1979, pp. 18, and others).

0010

The present invention is conceived in view of the stated problems. The object of the present invention is to provide a plasma display panel that enables luminance and luminous efficiency of cells at the PDP to improve, and to provide a production method of such a plasma display panel.

[MEANS TO SOLVE THE PROBLEMS]

0011

So as to solve the stated problems, the present invention is a plasma display panel, wherein plural pairs of display electrodes in column direction are provided on the first plate so as to be sandwiched between the first plate and a dielectric layer which is for covering the first plate, the first plate and a second plate are opposed to each other with a plurality of address electrodes in row direction therebetween, each area between one address electrode and a pair of display electrodes forms a cell, and a discharge gas is filled into each of cells, and wherein at least one of a thickness of the dielectric layer and a gap between a pair of display electrodes is adjusted to generate an electric field having 5V/cm・Torr or more equivalent electric field strength within the cells, and the discharge gas contains xenon with at least 5% pressure.

0012

When the PDP having the above structure is driven, ultraviolet light by means of Xe excimer (molecule beam) having about 173 nm is mainly generated in the discharge space (cell). The efficiency of exciting phosphors (irradiation efficiency) can be increased about at least two times as much as in a conventional case of Xe resonance line having about 147 nm. (Refer to "O plus E", No. 195, February

1996, pp.99-100). This is, as this document discusses, because the excitation spectrum for phosphors in each RGB color is inclined to increase, if the wavelength is in a range of 140-200 nm. The present invention utilizes the characteristic that, as wavelength of ultraviolet light irradiated on the phosphors becomes long within this range, the phosphor-excitation efficiency becomes high. Accordingly, the present invention has dramatically improved panel luminance and favorable luminous efficiency, compared to conventional PDPs.

0013

Specifically, so as to achieve the equivalent electric field strength, the thickness of the dielectric layer is set to be 10-25 μm.

An alternative method for achieving it is to constitute each display electrode by a bus line and a transparent electrode, and to constitute the dielectric layer by: a first dielectric layer covering the display electrodes; and a second dielectric layer accumulated over the first dielectric layer so as to correspond to where the bus line is, where a thickness of the first dielectric layer is 3-5 μm. In addition, one display electrode of each of the pairs may be provided with a protrusion that is opposed to the other of the pair, so as to have larger amount of ultraviolet light emission.

0014

Please note that the first layer and the second layer are respectively referred to as the first dielectric layer and the second dielectric layer, in the embodiments.

Here, it is possible to have more effect if a gap between

each pair of the display electrodes is 20-70 μm, and a pressure of xenon (Xe) within the discharge gas is 15-90%. Please note that these values are obtained by the embodiment examples of the present invention, which are detailed later.

0015

[EMBODIMENTS OF THE INVENTION]

1. Embodiments

(First embodiment)

The following describes an alternating current surface-discharge type plasma display panel (PDP), relating to the embodiment of the present invention. The PDP is similar to the conventional alternating current surface-discharge type PDP that is described above, in appearance and main structure. Therefore common features are not described below. In addition, the reference numbers in each drawing are the same between the two PDPs.

0016

FIG. 1 is a sectional view of a main part of the front panel 20 in the thickness direction thereof (i.e. direction z), in the PDP of the first embodiment. The main characteristic of the present PDP is that the Xe excimer (wavelength of about 173 nm) is emitted as a ultraviolet light. Because of this, the present embodiment differs from the conventional alternating current surface-discharge type PDP, in such as Xe content in the discharge gas, and a gap between the discharge electrodes 22 and 23, a thickness of the dielectric layer 24.

0017

More specifically, for the discharge gas, one of Ne-Xe type,

He-Ne-Xe type, and Ne-Xe-Ar type is used. In such a discharge gas, the content of Xe is set to be 5% or more. This is for providing, for the present PDP, necessary amount of Xe, so as to emit ultraviolet light mainly from excimers, instead of emitting conventional Xe resonance line (147 nm). It should be noted here that the pressure at which the gas is filled is set as about 500-800 Torr.

0018

In addition, the dielectric layer 24 is set to be thin as 10-25 μm, compared to a dielectric layer of a conventional PDP (which is about 50 μm). In addition, the gap between the display electrodes 22 and 23 is set to be 20-70 μm, which is narrower than that of the conventional PDP (i.e. about 100 μm). The object of these arrangements is for restraining discharge starting voltage of the present PDP, and to strengthen the electric field strength generated at the discharge space 38 (i.e. to at least 5V/cm・Torr equivalent electric field strength).

0019

According to the present PDP, having the aforementioned structure, discharge (sustaining discharge) starts at the gap between a pair of discharge electrodes 22 and 23 which is narrow as 20-70 μm, at the 150V of discharge starting voltage (being conventional discharge starting voltage) or even below. This helps restrain consumption electricity. After the discharge starts, the dielectric layer 24, being thinner than the conventional 35 μm, helps generate a strong electric field of at least 5V/cm・Torr in the cell 35, and so Xe excimers will be emitted constantly. Xe excimer strongly excites

the phosphor layers 31-33, thereby increasing the panel luminance to 2-3 times as much as that for the conventional PDPs. Specifically, the conventional PDPs normally have panel luminance of about 400cd/m^2, whereas the PDP of the present invention has panel luminance of about 800-1350cd/m^2. The specific data is given later, as embodiment examples.

0020

(Second embodiment)

The following describes another embodiment of the present invention. FIG. 2 is a sectional view of a front panel 20 relating to a PDP of the second embodiment, which is cut in the thickness direction. As shown in this drawing, the present PDP is characterized by setting a reference number 24 as the first dielectric layer, and that accumulates second dielectric layers 34 at positions that each correspond to the bus lines 22b and 23b provided on the surface of the first dielectric layer 24.

0021

The first dielectric layer 24 and the second dielectric layer 34 have thickness of about 3-5μm, and thickness of about 15-25μm, respectively. Specifically in the present embodiment, for the dielectric layers in the vicinity of the bus lines 22b and 23b (i.e. first dielectric layer 24 and second dielectric layer 34), at least about 15μm thickness is assured. As opposed to this, in the vicinity of a pair of electrodes 22 and 23, the dielectric layer (first dielectric layer 24) has lessened thickness such as to 3μm.

0022

During the address discharge to be generated between a bus

line (here, the bus line 22b) and the address electrodes 28, the present PDP having the above structures is able to perform discharge via the first dielectric layer 24 and the second dielectric layer 34, which constitute a thick dielectric layer on the whole. This helps favorable discharge because an electrical breakdown and the like are prevented at the dielectric layers. On the other hand, during the sustaining discharge thereafter, discharge starts via a very thin dielectric layer 24 which is about 3-5 μm. This makes the second embodiment have more restrained discharge starting voltage, as well as forming a strong electric field in the cell 35. Due to such a strong electric field, the Xe excimers are generated constantly, to excite the phosphor layers 31-33, thereby yielding as favorable panel luminance as the first embodiment.

0023

Note here that in each of the first and second embodiments, if the display electrodes 22 and 23 are arranged as follows, the electric field strength will further improve, which leads to more favorable generation of xenon excimers. FIG. 3 is a front view of the PDP front panel 20, seen in the direction z. In this drawing, the inside of a dotted frame is the cell 35. As shown in this drawing, the transparent electrode at one of the pair of display electrodes 22 and 23 (in this example, the transparent electrode 23a of the Y electrode 23) is formed to have protrusion shape with respect to the other electrode (in this example, X electrode 22), and to have a sizes of: x-direction width of 30 μm, and y-direction length of 150 μm, for example. Hereinafter, these types of electrodes are referred to as "needle-shape transparent electrode". One needle-shape transparent electrode 23a is provided

for each cell 35, in the direction x, on an intermittent basis. These needle-shape transparent electrodes are bridged via the bus line 23.

0024

According to the PDP having the display electrodes 22 and 23 of the aforementioned structure, so-called "unequal electric field" is generated in the sustaining discharge phase, because a tip of the needle-shape transparent electrode 23a of the Y electrode 23 will have concentration of static charge, compared to the X electrode 22("Discharge Handbook", Section 3, Chap. 1, pp. 115, and pp. 124). This unequal electric field causes a strong electric field within the cell 35, and so Xe excimers are generated favorably.

0025

Please note that to obtain a strong electric field, it is desirable to provide only one needle-shape transparent electrode 23a for each cell 35. This is for enhancing the concentration density of static charge as much as possible, so as to improve electric field strength.

Also note that the present invention is applicable to an opposed-type PDP, as well as to the surface-discharge type PDP.

0026

(1.Production of Front Panel 20)

First, on the surface of the front panel glass 21 (a thickness of about 2mm), an ITO whose thickness is about 0.12 μm is formed evenly, using a sputtering method (ITO being a transparent conductive material made of indium oxide and tin oxide). Thus formed ITO is then patterned using a photolithograph method, in a stripe pattern, to form transparent electrodes 22a and 23a, which have a width of 150 μm. (Note that

in the embodiment examples described later, the gap between a pair of display electrodes is set as 20-70 μm.) Here, if the transparent electrode 23a is formed to have a needle shape, as mentioned above, the masking having a desired pattern is provided in performing the photolithograph method.

0027

Here, the x-direction width of the needle-shape transparent electrodes may be about 1 μm, although the range of 10 to 50 μm makes production easier. In addition, the y-direction length thereof is desirably 150 μm, considering the cell pitch is 480 μm and the gap between a pair of the electrodes is 360 μm for normal 42-inch diagonal screen high-definition televisions.

0028

Following this, a light-sensitive silver paste is formed on the entire surface of he front panel glass 21. Then using the same photolithograph method, bus lines 22b and 23b, having width of about 30 μm, are formed on the transparent electrodes 22a and 23a, respectively. Then, this will be heated up to 550℃ to bake the silver paste, thereby forming the display electrodes 22 and 23.

Next, so as to form the (first) dielectric layer 24, a glass material having a softening point of about 600℃ or below (e.g. PbO-B_2O_3-SiO_2-Al_2O_3 glass having a softening point of 550℃-575℃) is pulverized using a wet jet mill (produced by Nanomizer) until the average diameter of the particle becomes 0.1 μm-1.5 μm. Here, it should be noted to set the pulverizing condition so that the maximum

diameter of the particle is within a range of three times as big as the average diameter of the particle.

0029

It should be noted that the PDP of the present invention is driven with higher electric field strength than the conventional PDP, and so it becomes necessary to prevent generation of air-bubbles, and to make the electric characteristic of the (first)dielectric layer 24 be as uniform as possible. Pulverizing the glass for the dielectric layer 24 finely helps prevent an undesirable electric breakdown to happen.

Next, this glass particles (55-70 weight %) is mixed with a binder (30-45 weight%) with a three roll. The binder is composed of either ethylcellulose or acrylic resin, and solvent of either terpineol or butyl carbitol acetate (1-20 weight % of the total binder), to produce a paste for dicoating or for printing purpose. Here, if it is necessary, 0.1-0.4 weight% of plasticizer may be added thereto, to improve printing characteristics. Possible candidates for the plasticizer are as follows: dioctyl phthalate, dibutyl phthalate, triphenyl phosphate, tri-n-butyl phosphate or dispersion, glycerol monooleate, sorbitol sesquiolate, homogenol (product name by Kao Corporation), and alkyl aryl phosphoric ester.

0030

Thus formed paste is then printed using a dicoating method or a screen printing method. When being dried thereafter, the paste is then baked at 560℃-590℃, which is a little higher than a softening point of the glass. The above processes form the (first) dielectric layer 24.

If the second dielectric layer 34 is to be formed thereafter, the following processes are performed.

0031

For example, a $PbO-B_2O_3-SiO_2-CaO$ glass having a softening point of 440℃-475℃ is pulverized with a ball mill, until the average diameter of the particle becomes about 2.5 μm. Then thus generated glass particles (55-70 weight %) is mixed with a binder (30-45 weight%) with a three roll. The binder is composed of either ethylcellulose or acrylic resin, and solvent of either terpineol or butyl carbitol acetate (1-20 weight % of the total binder), to produce a paste for dicoating or for printing purpose. Here, again, the plasticizer used for producing the first dielectric layer 24, described above, may be used if necessary.

0032

Thus formed paste is printed on the already formed first dielectric layer 24, using either a screen printing method or a dicoating method, and is dried. Then, the paste is baked at 520℃-590℃, which is 50℃-100℃ higher than the softening point of the glass used for the second dielectric layer 34, and is lower than the softening point of the glass used for the first dielectric layer 24.

Following this, on the dielectric layer 24(34), a protection layer 25 made of MgO is formed. Here, a CVD method (either a heating CVD method or a plasma CVD method) is used for forming a protection layer 25 having thickness of about 1.0 μm and made of magnesium oxide (MgO). The protection layer 25 is formed to be oriented towards one of the (100) plane and the (110) plane.

0033

It should be noted here that, as the (first) dielectric layer 24 and the second dielectric layer 34 become thin, panel luminance efficiency will be improved accordingly. Therefore, these dielectric layers should be formed as thin as possible, although it should be taken into consideration the withstand voltage (i.e. a level of voltage application that does not cause an electric breakdown).

(2.Production of back panel)

The address electrodes 28 (thickness of about 5 μm) are formed, by applying an electric conductive material over the back panel glass 27 at a predetermined interval, using a screen printing method. Here, the electric conductive material is mainly made of silver, and the back panel glass 27 is made of soda-lyme glass and has a thickness of about 2 mm. Here, the gap between two adjacent address electrodes 28 is set to be about 0.2 mm or smaller, for the purpose of producing a PDP of a high-definition television display having about a 40-inch diagonal screen.

0034

Following this, throughout the back panel glass 27, on which the address electrodes 28 have been formed, a glass paste with a thickness of about 20-30 μm is provided, then is baked (540℃-580℃), to form a dielectric film 29. The glass paste is prepared by mixing glass particles (having an average diameter of particles distributed in a range of 0.1 μm-3.5 μm) with 20 weight % of titanium oxide TiO_2 (having an average diameter of particles of 0.1 μm-0.5 μm). Note here that titanium oxide used here is for efficiently reflecting visible light emitted from the cell 35 towards the front panel 20. The content

of titanium oxide is normally 10-30 weight %, taking into consideration the optimal levels of whiteness and fluidity for the glass.

0035

Next, ribs 30 (height of about 100 μm) are formed on the dielectric film 29, so that each rib 30 is formed in a space formed between two adjacent address electrodes 28. The material of the ribs 30 is the same glass paste as is used for forming the dielectric film 29. These ribs 30 are for example formed by applying the glass paste by screen printing repeatedly, and then baking it.

After the ribs 30 are formed, three phosphor inks, which respectively include a red (R) phosphor, a green (G) phosphor, and a blue (B) phosphor, are provided for spaces created by the ribs 30, so that in each of the spaces, one phosphor ink is provided on the side walls of the two ribs 30, and on the surface of the dielectric film 29. Then, the result is dried and baked, thereby forming phosphor layers 31-33.

0036

The following lists one example of phosphor materials, conventionally used in PDPs.

Red phosphor : $(Y_xGd_{1-x})BO_3:Eu^{3+}$
Green phosphor : $Zn_2SiO_4:Mn$
Blue phosphor : $BaMgAl_{10}O_{17}:Eu^{3+}$
or $BaMgAl_{14}O_{23}:Eu^{3+}$

Each phosphor material has an average particle diameter of 3 μm. There are several methods considered for applying phosphor inks. However here, it is preferable to use a method called "meniscus method", by which a phosphor ink is applied using a very fine nozzle, to form

a meniscus (i.e. bridge formed by surface tension). This method is favorable for applying a phosphor ink at a target area evenly. Needless to say, the present invention is not limited to this method, and other methods such as a screen printing method may be used.

0037

The back panel is completed by the above operations.

Please note that in the above description, the front panel glass 21 and the back panel glass 27 are made of soda-lyme glass. However, this is only one example, and other materials may be used.

(3.Completing PDP)

The front panel 20 and the back panel 26, produced as above, are then attached to each other using an attaching glass. Here, the top parts of the ribs 30 are also attached via the attaching glass. By doing so, a PDP having adequate strength may be produced, even when the discharge gas pressure is higher than the atmospheric pressure, for example.

0038

Then, the discharge space 38 is evacuated to produce a high level of vacuum environment (about $8*10^{-7}$ Torr), and a discharge gas such as Ne-Xe type and He-Ne-Xe type is filled at a predetermined pressure. So as to obtain Xe molecular beams easily, a composition of the discharge gas to be filled is arranged to include 5 volume % or more Xe, and to set the filling pressure in the range of 500-800 Torr.

0039

The PDP of the present invention is completed by the above operations.

The production methods of the present PDP, as stated above, are substantially the same, except for some differences in the form and the structure of the display electrodes mentioned above, and for the forming of the protection layer 25.

The following summarizes the characteristics of the production method of PDP of the present invention, which have been described above. That is, the gap d between one pair of display electrodes 22 and 23 is set to be 20-70 μm, which is narrow compared to conventional PDPs. The film thickness of the (first) dielectric layer 24, on the transparent electrodes 22a and 23a, is set to be about 15 μm or less, to have higher electric field strength. Then, the pressure of Xe within the total discharge gas is set to be 5% or above. These characteristics constitute a structure that is able to obtain Xe excimers.

3. Quality comparison in embodiment examples

In accordance with the production method described above, PDPs of the first embodiment and the second embodiment, as well as a PDP having a needle-shape transparent electrode 23a, were produced as embodiment examples (the PDP having a needle-shape transparent electrode was produced based on the embodiments).

0040

Specifically, the embodiment examples use one of discharge gasses of: Ne-Xe type; Ne-Xe-Ar type; Ne-Xe-Ar-He type. The pressure of Xe within the total discharge gas is varied within a range of 5-90%, and also the discharge gas pressure (i.e. filling pressure of the discharge gas) is varied within a range of 500-800 Torr. The structures of the PDPs are set so as to have either a single-layer dielectric

layer or a double-layer dielectric layer. Furthermore, the structures are set such that a pair of display electrodes 22 and 23 are placed parallel, or one of which is formed as a needle-shape electrode. The combination of these alternatives enabled to produce 16 kinds of embodiment examples, and 4 kinds of comparison examples. It should be noted here that all the comparison examples have parallel display electrodes 22 and 23.

0041

Comparison tests were conducted, with regard to the quality of each PDP produced. The tests are directed to: panel luminance, a change rate in panel luminance; and electric field strength in the discharge space.

The panel luminance is measured under a condition that the PDP is driven at a discharge start voltage (Vs) of 150V, and at the frequency of 30kHz.

The change rate in panel luminance is measured in an accelerated life testing, i.e. in a more severe condition than the usual driving condition for PDPs (Vs=200V, and frequency of 50kHz for 24 hours). For the measurement, five pieces are prepared for each example No., and the change rate in luminance, before and after the driving, is calculated by taking an average of each five pieces.

0042

As for the electric field strength for the discharge space (i.e. cell), a publicly-known deriving expression was researched ("Discharge Handbook", Section 3, Chap. 2, pp. 128-129). According to this, if the electric field strength is set as E, the discharge gas pressure as p, and the gap between a pair of display electrodes

22 and 23 as d, the equivalent electric field strength is derived as follows.

(expression 1)

Equivalent electric field strength (V/cm・Torr);E/p=Vs/(pd)

Here, it is known that paschen law holds for the relation between Vs and a pd product, and that a minimum (Paschen minimum) on a Vs-pd curve signifies the lowest value of the discharge start voltage. In the present test, the equivalent electric field strength was calculated based on the expression 1, and taking into consideration varieties of parameters resulting from the three dimensional simulation for the discharge space 38 (cell 35).

0043

The following tables 1(a) and 1(b) relate to the embodiment examples No.1-10, No. 1-16, and the comparison examples No. 17-20. Specifically the tables show, for each example, a thickness of the dielectric layers 24 and 34, a gap between a pair of display electrodes 22and 23 (transparent electrodes 22a and 23a), a form of the transparent electrodes 22a and 23a, and the values such as discharge gas type and filling gas pressure, together with the test results mentioned earlier. Note that in the tables, the transparent electrodes 22a and 23a are referred to as "ITO".

0044

The comparison examples No. 17-20 are set to have structures common to the PDPs. That is, the film thickness of the dielectric layer 24 is set to be 30μm or thicker, a gap between a pair of display

electrodes 22 and 23 (transparent electrodes 22a and 23a) is set to be 80μm or more, and a Ne-Xe discharge gas contains 3-5 volume % of Xe. As the comparison examples of the table 1(b) show, such a conventional PDP has a panel luminance of about 400cd/m^2, which is also made public by a document (refer to "FLAT-PANEL DISPLAY", 1997, pp. 198).

0045

[TABLE]

(a)

Table (a)

NO.	No. of layers/ THICKNESS OF DIELECTRIC	DIELECTRIC THICKNESS ON THE TIP OF ITO	DISTANCE BETWEEN ELECTRODES (B/W ITO)	FORM OF ELECTRODES (ITO)	TYPE/ PRESSURE OF GAS	EQUIV. FIELD STRGTH IN DISCHARGE SPACE	ULTRA-VIOLET WAVE-LENGTH	PANEL LUMINANCE (cd/m²)	200V, 50kHz, CHANGE RATE AFTER 24 HRS
1	1: 15 μm	15 μm	70 μm	PARALLEL	Ne−Xe (90:10), 500Torr	8V/cm・Torr	173nm	890	−5.0%
2	1: 15 μm	15 μm	60 μm	1 SIDE PROTRUSION	Ne−Xe (90:10), 500Torr	10V/cm・Torr	173nm	920	−4.0%
3	2: 15 μm	5 μm	60 μm	PARALLEL	Ne−Xe (90:10), 500Torr	13V/cm・Torr	173nm	910	−3.5%
4	2: 15 μm	5 μm	50 μm	1 SIDE PROTRUSION	Ne−Xe−Ar (91:8:1), 600Torr	15V/cm・Torr	173nm	980	−3.2%
5	2: 20 μm	3 μm	30 μm	PARALLEL	Ne−Xe−Ar (91:8:1), 600Torr	16V/cm・Torr	173nm	950	−3.8%
6	1: 10 μm	10 μm	50 μm	1 SIDE PROTRUSION	Ne−Xe (94:6), 650Torr	11V/cm・Torr	173nm	915	−4.2%
7	2: 25 μm	5 μm	20 μm	1 SIDE PROTRUSION	Ne−Xe−Ar−He (83:6:1:10), 600Torr	20V/cm・Torr	173nm	995	−2.9%
8	1: 25 μm	25 μm	70 μm	PARALLEL	Ne−Xe (95:5), 500Torr	5V/cm・Torr	173nm	785	−5.6%
9	1: 15 μm	15 μm	70 μm	PARALLEL	Ne−Xe (80:20), 800Torr	8V/cm・Torr	173nm	920	−4.0%
10	1: 15 μm	15 μm	60 μm	1 SIDE PROTRUSION	Ne−Xe (70:30), 650Torr	10V/cm・Torr	173nm	1050	−3.5%

0046

(b)

No.	No. of layer / THICKNESS OF DIELECTRIC	DIELECTRIC THICKNESS ON THE TIP OF ITO	DISTANCE BETWEEN ELECTRODES (B/W ITO)	FORM OF ELECTRODES (ITO)	TYPE/ PRESSURE OF GAS	EQUIV. FIELD STRGTH. IN DISCHARGE SPACE	ULTRA-VIOLET WAVE-LENGTH	PANEL LUMINANCE (cd/m²)	200V.50kHz, CHANGE RATE AFTER 24HRS
11	2: 15 μm	5 μm	60 μm	1 SIDE PROTRUSION	Ne−Xe (50:50) ,500Torr	14V/cm · Torr	173nm	1150	−3.4%
12	2: 15 μm	5 μm	50 μm	1 SIDE PROTRUSION	Ne−Xe (30:70) ,500Torr	15V/cm · Torr	173nm	1200	−2.5%
13	2: 20 μm	3 μm	30 μm	1 SIDE PROTRUSION	Ne−Xe (20:80) ,600Torr	18V/cm · Torr	173nm	1350	−3.0%
14	1: 10 μm	10 μm	50 μm	1 SIDE PROTRUSION	Ne−Xe−He (20:30:50) ,600Torr	11V/cm · Torr	173nm	1320	−3.1%
15	2: 25 μm	3 μm	20 μm	1 SIDE PROTRUSION	Ne−Xe (10:90) ,500Torr	20V/cm · Torr	173nm	1350	−2.9%
16	1: 25 μm	25 μm	70 μm	PARALLEL	Ne−Xe (85:15) ,550Torr	5V/cm · Torr	173nm	850	−3.4%
17*	2: 30 μm	20 μm	120 μm	PARALLEL	Ne−Xe (96:4) ,450Torr	3.8V/cm · Torr	147nm	402	−15.0%
18*	1: 35 μm	35 μm	80 μm	PARALLEL	Ne−Xe (97:3) ,400Torr	4.0V/cm · Torr	147nm	395	−15.4%
19*	2: 30 μm	20 μm	100 μm	PARALLEL	Ne−Xe (95:5) ,500Torr	4.5V/cm · Torr	147nm	420	−14.5%
20*	1: 35 μm	35 μm	80 μm	PARALLEL	Ne−Xe (95:5) ,500Torr	4.0V/cm · Torr	147nm	415	−15.8%

* No.17〜20 ARE COMPARISON EXAMPLES

0047

4. Experimental result and consideration

First, the ultraviolet wavelength was measured while the embodiment examples No. 1-16 were driven. As a result, Xe excimers were mainly observed. Likewise, the ultraviolet wavelength was measured for the comparison examples No. 17-20, and Xe resonance lines (147 nm) were confirmed.

0048

As clear from the table 1, the embodiment examples 1-16, having generated Xe excimers, achieved 2 to 3 times as much panel luminance compared to the PDPs of the comparison examples No. 17-20, or even more. In addition, from each value for the change rate in panel luminance, it is revealed that damage to the phosphors is comparatively small in the embodiment examples 1-16 (about 1/3-1/5 of the comparison examples), and that the embodiment examples 1-16 have better resistance characteristics. This is considered because the excimer wavelength is longer than the resonance line (147 nm), and that because the energy with which ultraviolet light collides against the phosphors is not so much.

0049

From the test results of the embodiment examples No. 9-15, for example, it is revealed that as the Xe content among the discharge gas increases, the panel luminance will accordingly improve dramatically, compared to those of the conventional examples No. 17-20. In addition, even among the embodiment examples of No. 9-15, panel luminance is high for the example with more Xe content. That is, the amount of Xe excimers correlates with the Xe content in the discharge

gas. Specifically, if the Xe content is increased to the level of the embodiment examples, which is 8-9%, it becomes possible to produce a PDP having favorable luminous efficiency.

0050

In addition, again in this invention, it is confirmed that the generation of Xe excimer does not only depend on the Xe content in the discharge gas, but also greatly depends on the electric field strength in the discharge space 38. For example, even when the Xe content is about 5%, if an arrangement such as to make the thickness of the dielectric layer 24 thin as 25 μm, and to set the gap between a pair of display electrodes as 70 μm or less, it is possible to obtain equivalent electric field strength of 5V/cm・Torr. In such a strong electric field, generation of Xe excimer was observed. By generation of Xe excimers, the panel luminance of the PDP of the embodiment example No. 8 improved at least to about 2 times as much as the conventional PDPs.

0051

As seen as above, the generation of Xe excimers will also depend on the electric field strength of the discharge space 38. The electric field strength becomes strong as the dielectric layer becomes thin. If the dielectric layer has a single layer structure, the tendency is observed in the embodiment examples No. 1, 2, 6, 8-10, 14, and 16, and in the comparison examples No. 18 and 20. If the dielectric layer has a double layer structure, an excellent quality is obtained for examples with thinner first dielectric layer 24, which is directly influenced by the sustaining discharge. For example, in the embodiment example No. 5, even though its pressure of the Xe in

the discharge gas is only around 8%, it still achieves nearly as much panel luminance as 1000cd/cm^2, by making the first dielectric layer 24 thin. The similar things can be said for the embodiment examples No. 3, 4, 7, 11-13, and 15.

0052

In addition, the observation shows that the panel luminance is better for the structure in which one of a pair of display electrodes 22 and 23 is formed to have protrusion, compared to the structure in which both of a pair of display electrodes are parallel. This is considered to confirm, as stated earlier, that the static charge concentrates at the protruding electrode to yield a strong electric field, thereby favorably generating Xe excimers. For other matters, the panel luminance for the PDP improves as the gap between the pair of display electrodes 22 and 23 becomes narrow.

0053

[EFFECT OF THE INVENTION]

As stated above, the present invention is A plasma display panel, wherein plural pairs of display electrodes in column direction are provided on the first plate so as to be sandwiched between the first plate and a dielectric layer which is for covering the first plate, the first plate and a second plate are opposed to each other with a plurality of address electrodes in row direction therebetween, each area between one address electrode and a pair of display electrodes forms a cell, and a discharge gas is filled into each of cells, and wherein at least one of a thickness of the dielectric layer and a gap between a pair of display electrodes is adjusted to generate an electric field having 5V/cm・Torr or more equivalent electric field

strength within the cells, and the discharge gas contains xenon with at least 5% pressure. Therefore, the PDP has Xe excimer that has high efficiency in exciting phosphors. Therefore, the present invention has better luminous efficiency compared to the conventional PDP that uses ultraviolet due to Xe resonance line. In addition, the Xe excimer wavelength is longer (173 nm) compared to that of the resonance line (147 nm), and so damage to the phosphors will be small. This enables PDP to have better resistance characteristics. The production method of PDP of the present invention enables production of a PDP having such a favorable quality.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG.1 is a sectional view of the front panel of the PDP relating to the first embodiment.

FIG.2 is a sectional view of the front panel of the PDP relating to the second embodiment.

FIG.3 is a front view showing the variations of display electrodes in the second embodiment.

FIG.4 is a sectional perspective view of only the main structure of the alternate surface discharge type PDP.

[DESCRIPTION OF CHARACTERS]

20	front panel
21	front panel glass
22,23	display electrode
22a,23a	transparent electrode (ITO)
22b,23b	bus line

24	(first) dielectric layer
25	protection layer
26	back panel
27	back panel glass
28	address electrode
29	dielectric film
30	rib
31,32,33	phosphor layer
34	second dielectric layer
35	cell
38	discharge space

【DOCUMENT】 Drawings

FIG. 1

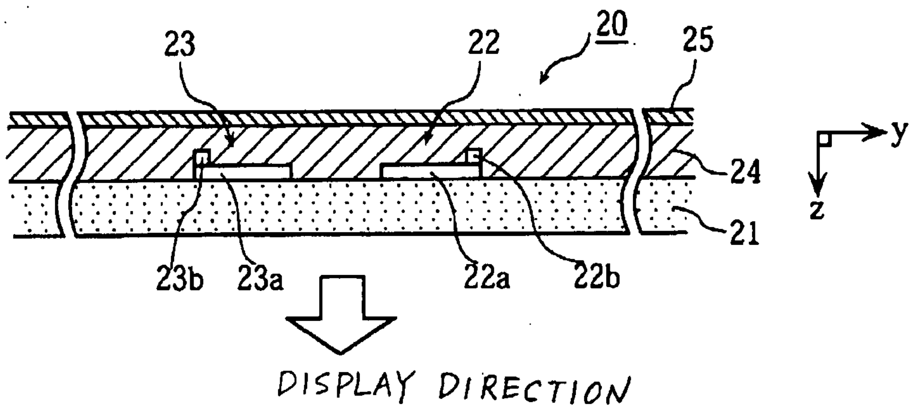


FIG. 2

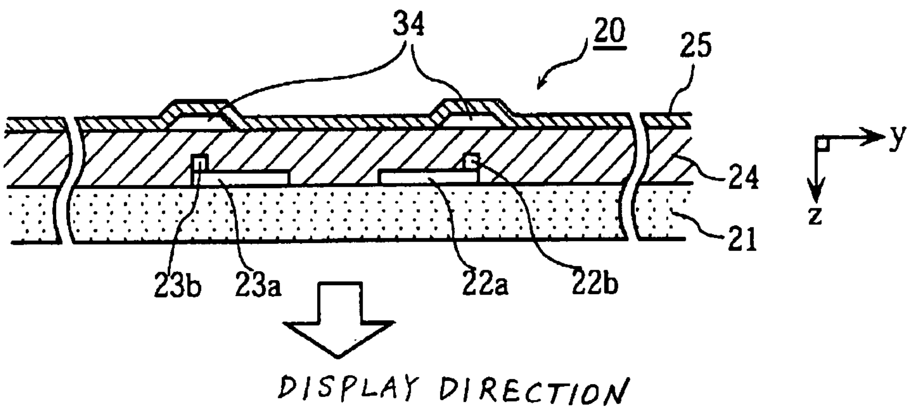


FIG. 3

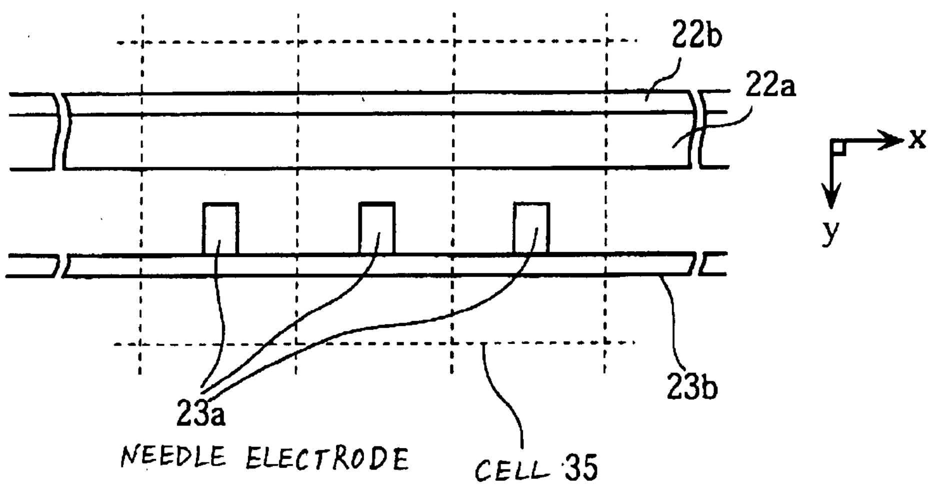
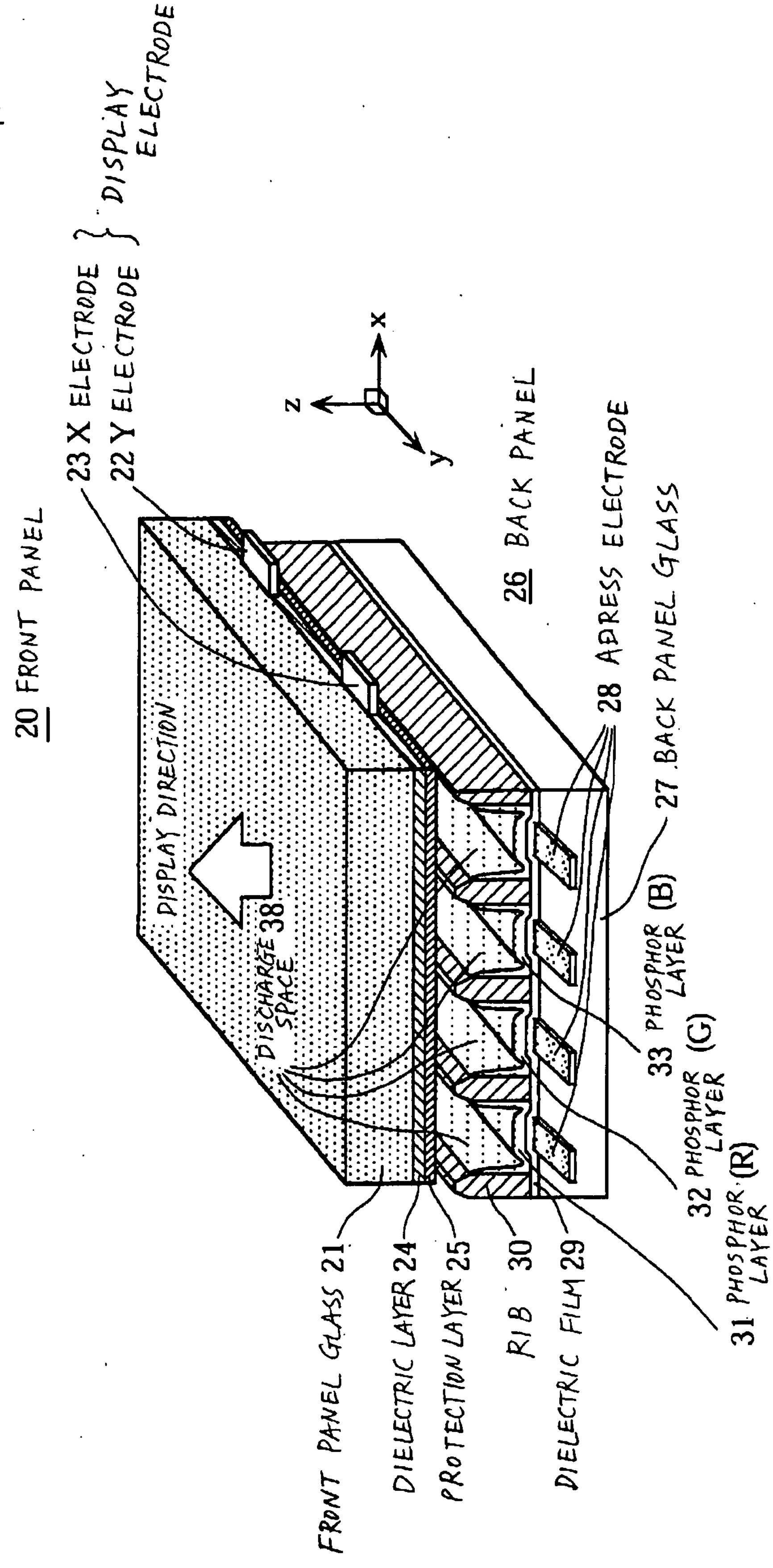


FIG. 4



20 FRONT PANEL
23 X ELECTRODE
22 Y ELECTRODE
DISPLAY ELECTRODE
z
x
y
26 BACK PANEL
28 ADRESS ELECTRODE
27 BACK PANEL GLASS
DISPLAY DIRECTION
DISCHARGE SPACE 38
33 PHOSPHOR LAYER (B)
32 PHOSPHOR LAYER (G)
31 PHOSPHOR LAYER (R)
FRONT PANEL GLASS 21
DIELECTRIC LAYER 24
PROTECTION LAYER 25
RIB 30
DIELECTRIC FILM 29

[DOCUMENT] Abstract

[SUMMARY]

[AIM] To provide a plasma display panel and a production method thereof, which greatly improve luminance and luminous efficiency for the cells of the PDP, compared to conventional PDPs.

[MEANS TO ACHIEVE THE AIM] A film thickness of a dielectric layer 24 is set as 25μm or less, which is thinner than conventionally. A gap between a pair of display electrodes 22 and 23 is set as 20-70 μm, which is narrower than conventionally. The stated arrangement enables the equivalent electric field strength of at least 5V/cm·Torr in a discharge space 38. Then, a discharge gas containing at least 5% of xenon is filled in the discharge space 38 at the pressure of 500 Torr or more, thereby generating ultraviolet light due to the molecular beam (excimer) of xenon, thereby exciting the phosphor layers 31, 32, and 33 to emit light.

[SELECTED FIGURE] FIG.1